

# Health Maintenance System (HMS) Hardware Research, Design, and Collaboration

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The Space Life Sciences division (SLSD) concentrates on optimizing a crew member's health. Developments are translated into innovative engineering solutions, research growth, and community awareness. This internship incorporates all those areas by targeting various projects. The main project focuses on integrating clinical and biomedical engineering principles to design, develop, and test new medical kits scheduled for launch in the Spring of 2011. Additionally, items will be tagged with Radio Frequency Interference Devices (RFID) to keep track of the inventory. The tags will then be tested to optimize Radio Frequency feed and feed placement. Research growth will occur with ground based experiments designed to measure calcium encrusted deposits in the International Space Station (ISS). The tests will assess the urine calcium levels with Portable Clinical Blood Analyzer (PCBA) technology. If effective then a model for urine calcium will be developed and expanded to microgravity environments. To support collaboration amongst the subdivisions of SLSD the architecture of the Crew Healthcare Systems (CHeCS) SharePoint site has been redesigned for maximum efficiency. Community collaboration has also been established with the University of Southern California, Dept. of Aeronautical Engineering and the Food and Drug Administration (FDA). Hardware disbursements will transpire within these communities to support planetary surface exploration and to serve as an educational tool demonstrating how ground based medicine influenced the technological development of space hardware.

## Nomenclature

ATP	= Authority to Proceed
CCPK	= Crew Contamination Protection Kit
CDCA	= Common Data Collection Application
CDR	= Critical Design Review
CHeCS	= Crew Healthcare System
CMO	= Chief Medical Officer
CMP	= Convenience Medications Pack
COTS	= Commercial Off the Shelf
CR	= Change Request
CTB	= Cargo Transfer Bag
DP	= Diagnostic Pack
EMTP	= Emergency Medical Treatment Pack
FDA	= Food and Drug Administration
GCAR	= Government Certification Approval Request
HASP	= HMS Ancillary Support Pack
HMS	= Health Maintenance Systems
HRF	= Health Research Facility
IO	= Intraosseous
ISP	= IV Supply Pack
ISS	= International Space Station
ISSP	= ISS Program
ITA	= Internal Task Agreement

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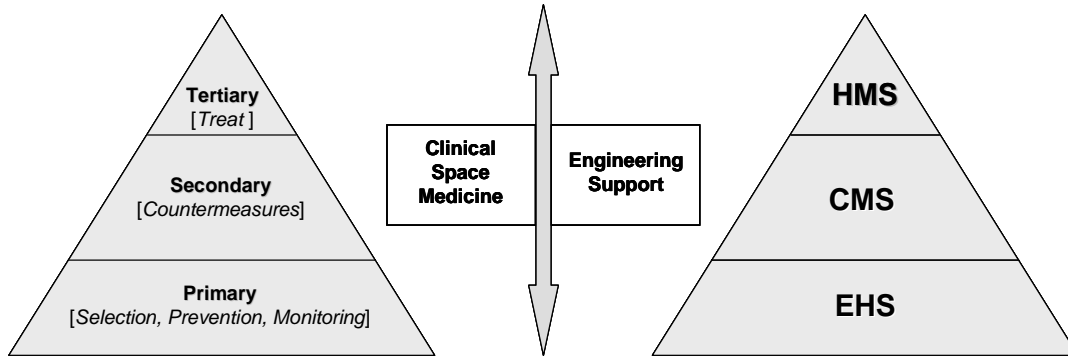
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## NASA USRP – Internship Final Report

IV	= Intravenous
JSC	= Johnson Space Center
LAN	= Local Access Network
MKR	= Medical Kit Redesign
MSP	= Medical Supply Pack
MTP	= Minor Treatment Pack
NASA	= National Aeronautics and Space Administration
OMP	= Oral Medications Pack
PDR	= Preliminary Design Review
PEP	= Physicians Equipment Pack
PM	= Project Manager
RF	= Radio Frequency
RFID	= Radio Frequency Identification
RID	= Review Item Disposition
RAESR	= Risk Assessment Executive Summary Report
SAR	= Systems Acceptance Review
SLSD	= Space Life Sciences Directorate
SRR	= Systems Requirements Review
STS	= Shuttle Transport System
TIMP	= Topical and Injectable Medications Pack
USC	= University of Southern California
USRP	= Undergraduate Student Research Project

## I. Introduction

The Space Life Sciences directorate (SLSD) (Fig. 1) strives to optimize crewmembers overall health and performance by maintaining the crew's health (tertiary), assessing environmental factors (primary), and providing countermeasures against microgravity effects (secondary). A subdivision of SLSD entitled Crew Health Care Systems (CHeCS) strives to fulfill that mission by reinforcing each level of astronaut care.



**Figure 1. Hierarchy of SLSD function CHeCS support.**<sup>2</sup> Engineering support provided from CHeCS supports primary, secondary, and tertiary levels of care in SLSD.

This project concentrated on maintaining the crew's health through the Health Maintenance Systems (HMS). This branch focused on treating contingencies as well as assessing and diagnosing medical conditions. Currently aboard the ISS a combination of packs, housed within the CHeCS rack (Fig. 2) provide tertiary care. The HMS includes; Advanced Life Support Pack (ALSP), Ambulatory Medical Pack (AMP), Crew Contamination Protection Kit (CCPK), Crew Medical Restraint System (CMRS), Respiratory Support Pack (RSP), the HMS Ancillary Support Pack (HASP) and a few other hardware and software items. Together for over 10 years these packs have helped maintain crewmembers health.



**Figure 2. CHeCS rack aboard the ISS.** This rack houses equipment used for contingency purposes include ALPS, RPS, AMP, and HASP.

The AMP (Fig. 3) is comparable to an upgraded first aid kit providing hardware to analyze blood, treat minor wounds, perform dental checks, supply surgical hardware, and administer medications (oral and topical).



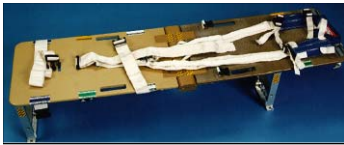
**Figure 3. Ambulatory Medical Pack and subpacks.** Houses medications, blood analyzer equipment, surgical, and dental tools.

To save the life of a crewmember the ALSP (Fig. 4) provides treatment for advanced cardiac and basic traumatic protocols. Hardware can also be used to sustain the crewmember under rescue circumstances. Figure 4 provides a glimpse of ALSP contents which include; an airway subpack, drug subpack, emergency surgery subpack, IV Administration subpack, Blood Pressure cuffs, and urinary leg bags.



**Figure 4. Advanced Life Support Pack (ALSP) and subpack.** *Used primarily for contingency purposes.*

To stabilize the patient under contingency operations the CMRS (Fig. 5) helps ground the crew for defibrillation and serves as a mode of transportation. To assess cardiac function the LifePAK 1000 provides defibrillation to a crewmember experiencing cardiac arrhythmia. Additionally, to sustain the life of a crewmember the RSP yields a constant flow of oxygen, and enables manual and automatic ventilation.

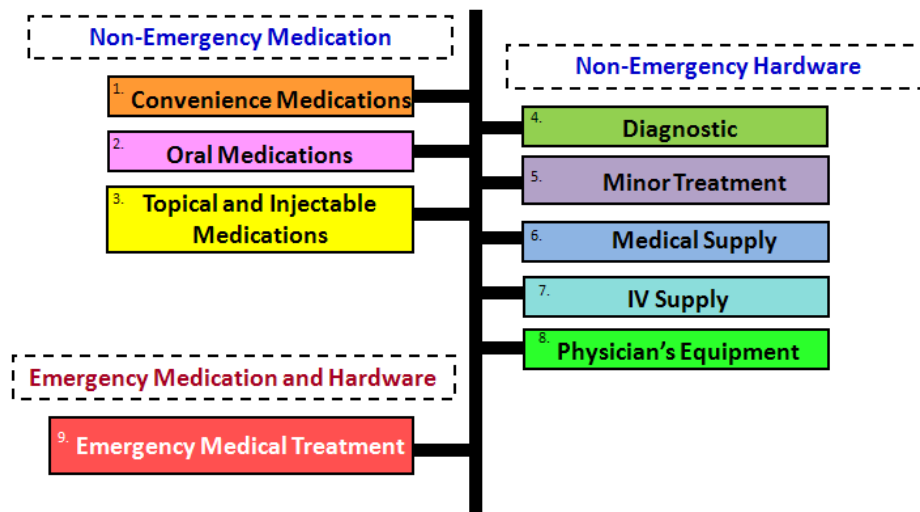


**Figure 5. Crew Medical Restraint System (CMRS).** *Stabilizes the patient and is used to administer defibrillation.*

To resupply the above units the HASP provides saline, battery packs, and ultrasound gel as needed from ground to the ISS.

Together these packs have supported the crewmembers for many years. However, since their development medical standards have changed, a need to improve operational efficiency has developed, and improving methods of resupply has motivated the redesign of the ALSP, AMP, and HASP.

The ALSP, AMP, and HASP have been redesigned into nine medical kits intuitively dividing the placement of medication and hardware (Fig. 6). The kits include the following; Convenience Medications Pack (CMP), Oral Medications Pack (OMP), Topical and Injectable Medications Pack (TIMP), Medical Supply Pack (MSP), Minor Treatment Pack (MTP), Medical Diagnostic Pack (MDP), IV Supply Pack (ISP), Physicians Equipment Pack (PEP), and Emergency Medical Treatment Pack (EMTP).



**Figure 6. Medical Kit Categorization.**<sup>2</sup> *Medical kits are divided into Non-Emergency Medication, Non-Emergency Hardware, and Emergency Medication and Hardware.*

The Non-Emergency Medication packs include Convenience, Oral, and Topical and Injectable Medications. (Fig. 6) The CMP houses the most often used medications. The OMP and TIMP both contain medications used less frequently but are essential to the health of crewmember.

Non-emergency hardware will be used to perform check-ups, diagnose afflictions, and treat minor contingencies. The MDP houses electronic equipment to assess the health of crewmembers through; blood pressure cuffs, a stethoscope, an ophthalmoscope, a tonometer, and many other items. The MTP is most comparable to the AMP containing treatments for minor wounds, catheters, dental and surgical tools. The MSP will house items needed for medical treatments and will be used in conjunction with other kits. The IV supply contains IV fluid, administration sets, pumps, catheters, and other materials needed for administration. The PEP will be used strictly by a physician Chief Medical Officer (CMO) and contains several kits to aid with diagnosis.

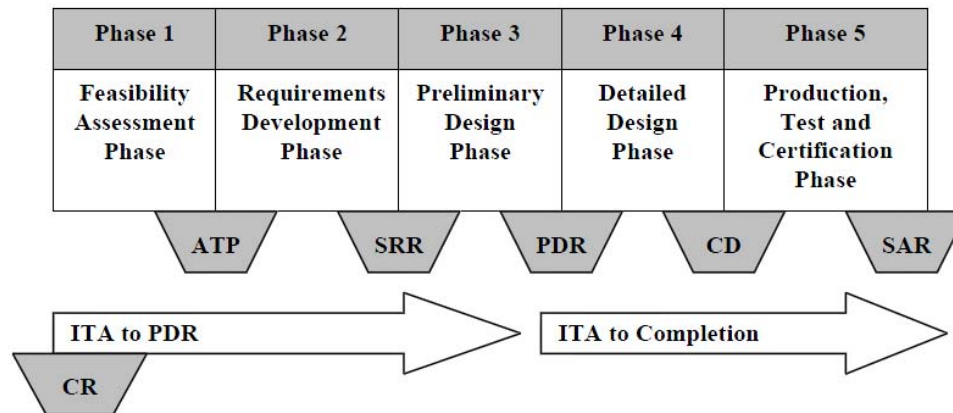
Lastly the EMTP will be used under emergency situations to sustain the life of a crewmember. Much of the hardware contained within this kit includes items located within the ALSP including; AMBU bag, medications, and Intraosseous (IO) infusion devices.

To redesign the ALSP, AMP, and HASP into the Medical Kits the Flight Hardware Design Process Model must be followed (Fig. 7).<sup>1</sup> A discussion will detail how this process was supported by integrating clinical and biomedical engineering principles. Additionally, this redesign has sparked innovative engineering solutions involving Radio Frequency Identification (RFID) in inventory tracking. Research interest has also developed to mitigate calcium encrusted deposits in the International Space Station (ISS). Through these redesign, testing, and research phases a need has developed to redesign the CHCS SharePoint architecture allowing for maximum efficiency. Lastly, details will be provided on the collaborative efforts disseminated through the University of Southern California, Dept. of Aeronautical Engineering and the Food and Drug Administration (FDA).

## II. Description

### A. Medical Kit Redesign Project

To redesign the medical equipment a series of phases outlined in Fig. 7. must occur before the final product can fly. Authority to Proceed (ATP), Systems Requirement Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), and System Acceptance Review (SAR) represent control gates that once approved initiate the following phase. Phase 1 was entered when a change request (CR) was submitted to the ISS Change Directive 01317. On September 2008 this approval was granted and expectations were set in place by SLSD and stakeholders regarding allocation of resources, scheduling, associated costs, and operational functions.<sup>1</sup>



**Figure 7. Flight Hardware Design Process Model.** *This models the Medical Kit Redesign Process.*

### *1. Requirements Development Phase*

During Phase 2 requirements were defined based on input from the medical community, environmental, materials, human factors, and several other organizations. Once the requirements were finalized the NASA Project Manager (PM) approved the requirements and in December of 2008 the SRR was held to obtain approval from the Space Medicine Division and ISS Program (ISSP) Vehicle Office to proceed to the next phase. During the SRR, the entire community (e.g. ISSP, Safety, Operations, Crew Office, , Materials, and Systems) assessed requirements and voiced concerns through Review Item Dispositions (RIDs). Each RID was assessed and concurrence led to the modification of requirements or addition of new ones.

### *2. Preliminary Design Phase*

Completion of the SRR marked the initiation of the Preliminary design phase. During this phase a design implementing all requirements was developed and assessed by the community. To support this phase, hardware was identified and a design was developed for nomex enclosures (Fig. 8). Once approved the PDR phase ensued, appealing to the community who voiced concerns through RIDs. Acceptance of PDR occurred in April 2010.

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Final approval to proceed received from the Space Medicine Division and the ISSP Vehicle Office.

**Figure 8. Nomex enclosure design.** *This design was originally implemented meeting the requirements set in the Requirements Development Phase*

### *3. Detailed Design Phase*

During the Detailed Design phase engineering drawings, tests, and analysis of designs was produced to reflect the final design.<sup>1</sup> This information was organized and presented to the Crew Office, Operations, Systems, Materials, Structures, and Safety at the CDR. Once again the community voiced concerns through RIDs. Suggestions were not major design changes instead improvements or modifications to the current design. Final CDR approval was received from the Space Medicine Division and the ISSP Vehicle Office in October 2010.

A RID database was developed based on the initiator, then each RID was assessed and research was performed before concurrence was established. Representative RIDs incorporated into the design include those listed in Table 1.

**Table 1. Synopses of Review Item Dispositions.** *Concerns about the design were voiced through RIDs*

L/I	Document, PG#, Requirement #	Concern	Changes
1	3.1.1	Internal hardware protection during transportation, launch	Establish packaging methods for each piece of hardware
2	MKR-10-001	Disposal of label along with bag containing it	All non-consumable hardware was assessed and human factors was consulted
3	MKR-10-001	Extensive use of ziplocks	Assess each piece of hardware and provide best method of securing (E.G. velcro, straps, nomex pouches)
4	MKR-10-001, drawings	Op nom registry	Op Nom was established for each piece of hardware, submitted to CR, and incorporated into drawings
5	MKR-10-001	Insufficient clearance margin	Max. size of final kits will be no larger than 14.75" W x 16.5"H and fit into the CHECS RSR with a 1" margin on all sides
6	MKR-10-001 document	Medication quantities	
7	MKR-10-001 document	Description of medications	
8	MKR-10-001 document	Missing hardware	
9	MKR-10-001	Part Description Modification	
10	MKR-10-001	Updated hardware	Apply correct P/N and quantities and add to kit
11	MKR-10-001	Provide Latex- free hardware	Incorporated
12	MKR-10-001	Placement of Ambu bag label	Provide tether attachment
13	MKR-10-001	Carpject Injector packaging	Ensure heat sealed bags are reclosable
14	MKR-10-001	Labels color/contrast	Comply with human factors codes
15	MKR-10-001	Provide sharps box for all sharps	Sharps box supplied
16	MKR-10-001	No bubble wrap on oral medications	Complied
17	MKR-10-001	Bags enclosing hardware should be clear	Complied
18	MKR-10-001	Apply familiar names for medications	Complied
19	MKR-10-001	Tubing containment	Proper packing was implemented
21	MKR-10-001	Do not include blister packs	Complied
22	MKR-10-001	Indicator Card inside CHECS rack	Complied



**Figure 9. Enclosure of a dental tool.** All dental and surgical tools were mocked and assessed for safety concerns.

To complete Phase 4 a Phase II safety review was performed and the following items were assessed; sharps containers, biohazard waster bags, syringes, vials, surgical and dental tools. To prevent perforation of the sharps each surgical and dental tool was placed into a stabilizer card, then enclosed by an 8mL bag, all tools were then packaged respectively into an 8 mL bag for dental tools and another 8mL bag for surgical items (Fig. 9). Every glass vial was covered with prescription tape to prevent leakage if broken. Indication of toxic materials was also discussed.

To organize the accepted RIDs, incorporate safety concerns, and track medication/hardware changes a hardware database was developed. It provided information about each medical kit, part descriptions, part numbers, concentration/volumes, quantities, and packaging.

The control gate leading to Phase 5 was the completion of CDR and Phase II safety review.

#### 4. Protection, Test, and Certification Phase

This project is currently in Phase 5 where the design to baseline is being implemented. The Medical Kits have been mocked up and hardware is being tested to ensure each requirement is met. Requirements and potential hazards have been provided in the Risk Assessment Executive Summary Report (RAESR). Communication has been established with vendors to assess hardware and ensure the Commercial Off the Shelf (COTS) requirements meet the appropriate standards and regulations (Table 2).

**Table 2. Verification of Requirements.** Organizes information obtained by vendor to ensure requirements are met.

Vendor Data Sheets	Reason
Digital Thermometer	showing plastic covering on LCDs
Blood Pressure Monitor	showing plastic covering on LCDs
Tonometer	showing plastic covering on LCDs
CO-Oximeter	showing plastic covering on LCDs
Examination Mirror	showing mirror is made of plexiglass
PanOptic	lenses are recessed and the bulb is completely contained within the devices
Otoscope	lenses are recessed and the bulb is completely contained within the devices
Dermabond	designed with a plastic vial to contain shattered particles
EpiPen	potential fragile materials inside the EpiPen are enclosed within the device to preclude shatterable material release
Laryngoscope	bulb is recessed inside the handle
Needles and Catheters	needles and IV catheters are provided with caps/covers and equipped with safety devices
Blunt Cannulas	blunt cannulas are provided with plastic caps/covers
Cap Vial Adapters	cap vial adapters are provided with plastic containers
Scalpels	scalpels are provided with caps/covers and equipped with a safety device
IV saline fluid	IV fluid is contained within a plastic housing with an external overwrap



The mocked up kits addressed each accepted RID beyond those contained in Table 1. Implementation can be divided into safety, operational, human factors, and design changes.

### Safety

To address the safety concern of protecting internal hardware during transportation and launch every piece of



**Figure 10. Stabilization of emergency hardware.** *Each piece of hardware was assessed for optimal packaging.*

hardware was assessed and optimal packaging was devised with the addition of bubble wrap, pigmat, or containment in a ziplock bag. To limit the use of ziplocks certain items were tethered to the kit (Table 1 L/I 3). For example, the AMBU bag and stethoscope located within the emergency medical kit have specialized holders and tethers to provide easy access while supporting the hardware (Fig. 10). Additionally, sterilization techniques were evaluated and a plan was devised to reduce the bulk of dental kits. It was decided each would be provided with a unique stabilization card then uniquely heat sealed, all would then be contained in the dental kit.

### Operations

To comply with L/T's 6-10 (Table 1) the Topicals and Injectables, Oral Medications, and Convenience medications were repackaged, bubble wrap was removed, concentrations/volumes and quantities were updated, glass packaging was implemented, and light sensitive materials were provided with amber colored bags. To ensure proper representations of medications compatible footprints have been provided and implemented. Together the pharmacy and operations have worked together to prevent user confusion by separating look a like and sound a like medications.

### Design Changes

Each piece of non-consumable hardware was assessed and ensured labels were strategically placed (Table 1 L/I 2). For example, a label would not be placed on each individual bandaid but could be placed on stethoscopes. Decal labels will be placed on electronic hardware and other equipment that cannot support traditional labels.

Another design change involved modification of nomex enclosures to comply with L/I 5 (Table 1). Individual Nomex bags were assessed and the contents were distributed to ensure the 14.75" W x 16.5"H dimensions were feasible. Other features of the nomex were addressed, including the addition of rows of Velcro with an inch separation, bulk was removed from the kit, handles were moved to provide more space in lockers, and extra fabric laid over the zipper to mitigate fire hazards (Fig. 11).

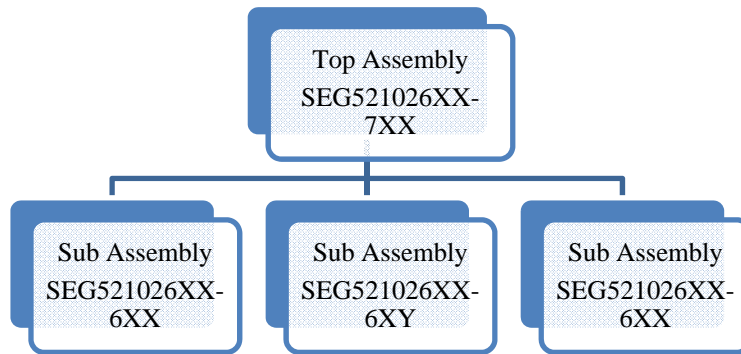


a) b)  
**Figure 12. Comparison of original and current Medical Kit design.** *Once all design changes were implemented a variation was noted in the final design (b).*



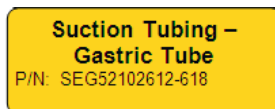
**Figure 11. Current design for nomex enclosures.** *When compared to Fig.8 several design changes can be noted resulting in an efficient design.*

Paralleling this effort was the submission of; registered names, part numbers, and cage codes for every piece of hardware. The NASA P/N was based on engineering drawings and organized by levels. For example, the top assembly number for the surgical equipment would identify the kit and subassembly numbers yielded a SEG521026XX-6XX level corresponding to the surgical tools (Fig. 13).



**Figure 13. Model of how NASA part numbers in engineering drawings are modeled.** The top assembly number corresponds a kit containing varying items, those varying items compose the sub assembly level.

In preparation for accommodating the approved hardware names, labels have also been developed. Issues encountered with the previous labels were addressed at a meeting attended by Med Kit stakeholders. Concerns were expressed and the following criterion was established for the new labels (Fig. 14). A specific format was provided for hardware, medications, subassemblies, and top assemblies. Figure 14 provides an example of a hardware label, Figure 15 is a kit label, and Figure 16 is a Medical Kit label. for the packing containing the suction tubing, and Figure 16 provides a label for the Medical Kit.



**Figure 14. Hardware label.** Format, content, color, and name was assessed for each piece of hardware.

ILMA Hardware	
P/N: SEG52102612-702	
ILMA Endotracheal TubeSuction -7.5	P/N: SEG52102612-609
ILMA Endotracheal TubeSuction -7.0	P/N: SEG52102612-608
ILMA – Large	P/N: SEG52102612-611
ILMA – Small	P/N: SEG52102612-610
ILMA Stabilizer Rod	P/N: SEG52102612-612

**Figure 15 Kit Label.** Format, content, color, and names were established for each kit (not to scale).



**Figure 16. Top assembly Medical Kit Label.** *Once again the format, color, and content was chosen for each Medical Kit (not to scale).*

Once the prototype has been approved and all requirements have been verified the design can then be certified and the “build-to baseline”<sup>1</sup> will be established. Phase 5 terminates when the Government Certification Approval Request (GCAR) and a Systems Acceptance Review (SAR) takes place, shortly thereafter the kits will be delivered to the ISS by the Russian Progress Vehicle 42P in April 2010.

## **B. SharePoint Website Redesign**

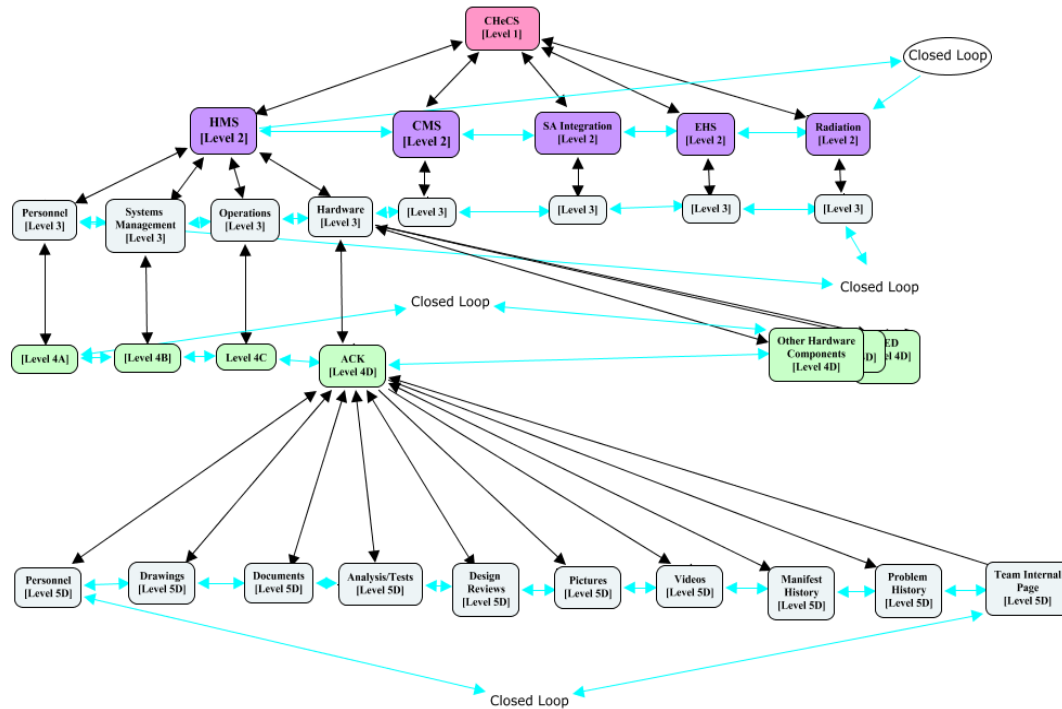
The Medical Kit Redesign team along with the other hardware and operations teams within CHeCS share files, test results, and data with other individuals working CHeCS. SharePoint has met this need by facilitating collaboration through file sharing. However organizational issues often result from the varying interpretation of where information should be stored. To improve the efficiency individuals from HMS, EHS, Radiation and CMS developed systemic requirements. An architecture was developed to organize information based on the logical flow of information. Fig. 17 provides a site map modeling the structure from top level down. An overarching goal of this development was to provide a 1 click away system to efficiently provide access from one folder to the next. (Fig. 17)

That philosophy will be implemented throughout the CHeCS sharepoint site. An example is provided in Fig. 18 representing a screenshot of the HMS homepage. That homepage is Level 2 (Fig. 18) and is 1-click away from all subgroups (Level 3, 4A-D, and Levels 5A-D). Once on that homepage, sibling sites (fellow Level 2) can be assessed as well as their respective subgroup (Level 3).

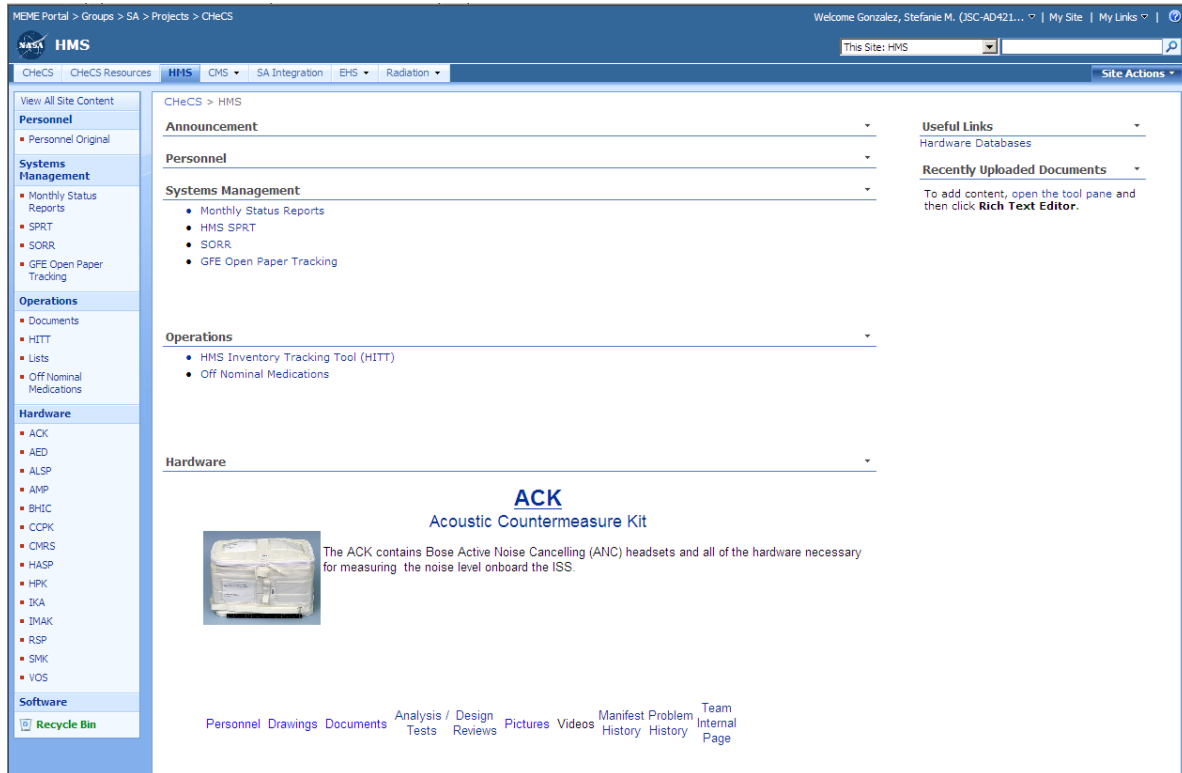
Returning to the HMS homepage, say for example the picture of ACK has been selected (Fig. 18). This corresponds to the Level 4D subgroup. Once entered this site is 1-click away from Levels 1, 2, 3, and 4A-4D. However, 2 clicks must be used to assess the Level 4 corresponding to CMS, EHS, SA Integration, and Radiation.

The final implementation can be assessed through the selection of an ACK sub site, Level 5D. If the Analysis/Tests were selected under ACK then all fellow Level 5D sites could be assessed. Levels 1, 2, 3, and 4A-4D could would also be available through 1 click away. However, if a 4C Level was chosen next, it would take 2 clicks to get to Level 5D.

This architecture enables a powerful navigation and the user will be able to place information in logical sites. Additional features have been incorporated including a useful links button on each webpage and soon a webpage dedicated to recently uploaded documents will be established.



**Figure 17. Site Map of CHeCS SharePoint.** *This site demonstrates the skeleton that will be established in HMS, CMS, EHS, and Radiation.*



**Figure 18.** Screen shot of HMS homepage. *Skeleton established in Fig. 17 has been implemented.*

### 1. Future Work

To make SharePoint fully functional several changes must occur, it begins with establishing the skeleton for EHS and Radiation. Once implemented, the sites can be populated, organized, and extraneous information will be extracted. If CHeCS personnel feel the structure is appropriate then the skeleton will be expanded and the CHeCS homepage will be re-organized. Through these efforts it is hoped collaboration will be more efficient.

## C. Portable Clinical Blood Analyzer (PCBA)

PCBA hardware, until recently, was located within the AMP in the ISS. A goal of this project is to develop a method of detecting calcium in urine to measure calcium deposit encrustations aboard the ISS. A series of experiments was developed to measure urinary calcium deposits through a Portable Clinical Blood Analyzer (PCBA). To accurately provide this measurement calculations were made to ensure the calcium concentration would fall within the detectable range of the PCBA.

### 1. PCBA Testing

To validate the function of PCBA units they were tested with control cartridges. If accurate readings had been obtained testing would have ensued, however it was discovered the majority of hardware needed firmware updates. To test an industry i-STAT Portable Clinical Analyzer was used along with an i-STAT cartridge, 60ml sample of urine, and 16ml of distilled water. Several trials were performed with the urine sample and other concentrations but accurate readings were not obtained. Collaboration with other departments have been established to mitigate this issue.

## 2. Future Plans

Once a urine sample has proven to fall within the vendor's range fifteen urine samples will be collected from an individual through the course of a week. Daily four samples of 60ml will be taken, one set in the morning and the other in the afternoon. For each set one sample will be delivered to the pharmacy for calcium concentration analysis and the other will be used for the i-STAT PCBA system. Therefore in the morning two samples of urine will be taken, one sample delivered to the pharmacy and the other for PCBA testing. The same method will be applied in the afternoon. At the conclusion of weekly testing twenty urinary Calcium concentrations will be obtained. A 2-sample t- test can be performed to assess if the mean Calcium concentration from the pharmacy and the PCBA are statically different. If statistically different, then the method will be revised for monitoring urine calcium.

## D. Radio Frequency Identification (RFID) Testing

Medical kits house over 200 individual components. Astronauts inventory these items in addition to managing an inventory comprising contents within more than 500 cargo transfer bags (CTB) using barcode technology. As imagined this process absorbs crewmembers time, averaging over 125 hours per assessment. To increase efficiency research is being performed to replace traditional barcodes with RFID tags. RFID tags provide a unique identification transmitting information in seconds.

RFID tags are essentially upgraded barcodes, containing integrated chips programmed by RFID readers (Fig. 19). RFID readers emit Radio Frequency (RF) energy through the antennas that power RFID tags. In turn the tags powered integrated circuit alternates between receiving and reflecting the incident RF power. The reflected RF pulses provide a unique identification of the programmed item along with other optional stored user information.

An RFID reader system is being developed to read first aid and blood sampling items stored in the Health Research Facility (HRF) Kit. (Fig. 19) This kit is currently stored in a 2-drawer pantry aboard the ISS. All ziplocks and pallet items are uniquely tagged, thus each item is distinguishable. An RF liner was developed to enclose these items and localize the electromagnetic energy, which can improve read accuracy, preclude unintentional reading of tags external to the liner, and also prevent noise. To read each individual item antenna feeds were strategically placed within the RF enclosure.



**Figure 19. Health Research Facility Kit Prototype.** *Nomex enclosure housing ziplocks and pallets (19a and 19b) and the constructed RFID case (19c).*

## 1. Testing



Several variables were taken into consideration, including frequency, power, duration of RF penetration, and antenna location. The number of read tags corresponding to each feed location was recorded, and the composite value provided the total number of read tags. Statistical tests assessed three feed locations that varied over time. Each feed was assessed to determine the maximum RF penetration.

## 2. Results

A final implementation will likely involve multiple feed locations that will be sequentially switched by a reader. This is necessary to ensure an acceptably high read accuracy. Thus, the data was evaluated as a composite so that a tag was considered successfully read if it was read through any one of the three feed locations. The composite reading was assessed at 20, 15, and 10 second read durations. The mean percentage of read tags at 20 seconds was  $97\% \pm 2\%$ . (Fig. 20) with a 95% confidence interval of 96% to 98%. This value was statistically different from the mean percentage of read tags at 10 seconds ( $89\% \pm 4\%$ ) as well as the mean percentage of read tags at 15 seconds ( $89\% \pm 6\%$ ).

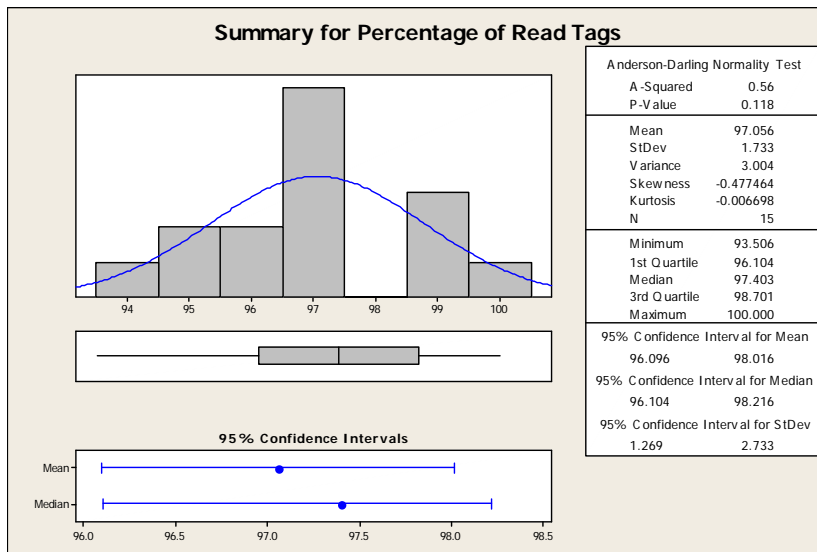
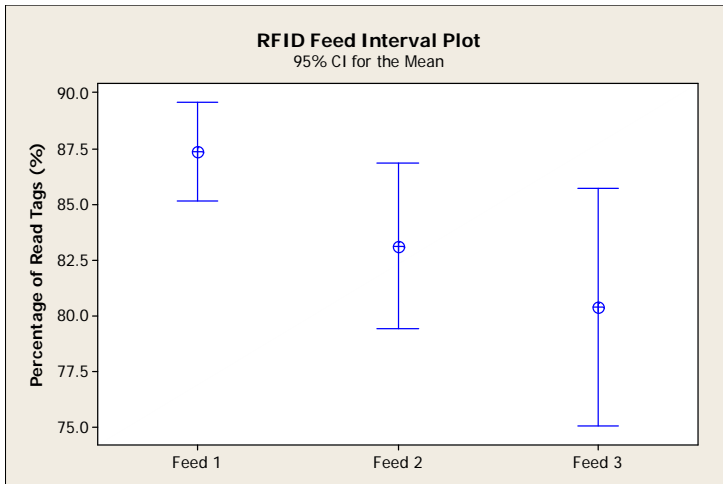


Figure 20. Statistical Assessment of Identified Tags During 20 seconds of RF Penetration. The percentage of read tags was assessed when the composite value was taken from three feed locations.

In addition to determining the total number of tags read, it is also important to determine if any particular feed location is more effective than the other two. Feed locations were compared at 20, 15, and 10 seconds to determine the location of maximum RF penetration. From the interval plot located in Fig. 21 it was concluded that the feed locations were not statistically different from one another. However, it can be noted that the first feed location had the highest percentage of read tags and the lowest variance.





**Figure 21 - Comparison of feed locations at 20 seconds of RF penetration.** *The confidence interval of each feed location overlapped indicating no statistical difference between feed locations.*

### 3. Conclusion

The overarching goal of the RFID testing described herein is to determine the feasibility of the liner approach and to refine the design, particularly with respect to the number of feeds required and optimal feed locations. . The work completed has established that two or three feed locations should be used in order to assure high read accuracy. It was found that use of three feed locations resulted in a mean read accuracy of 97%. Recommend future work includes data reduction to determine the value of three feeds compared to just two.

Several milestones must be completed to complete this medical kit project. The first of these is to develop an HRF liner kit, which would be followed by integration of the feeds. This would be followed by testing of the wireless radio that communicates from the kit to the ISS wireless Local Access Network (LAN). Prior to operational use, it is likely that this technology will be tested on-orbit as part of an ISS Detailed Test Objective. Once approved, over 125 hours of crewmember time will be freed per inventory assessment.

### E. Hardware Disbursement

Research efforts and collaborative events have not been limited to the JSC community. Ties have been established with the University of Southern California (USC), Dept. of Aeronautical Engineering and the Food and Drug Administration (FDA). Hardware loans to these organizations are in work to support planetary surface exploration and to serve as an educational tool demonstrating how ground based medicine influenced the technological development of space hardware.

Medical hardware flown in space will be exhibited at FDA White Oaks Maryland location. The FDA research division was interested in showcasing how medical hardware used by astronauts in orbit is regulated by the FDA. Four pieces of hardware were chosen based on those qualifications including IV Infusion Pump, Portable Clinical Blood Analyzer (PCBA), AED, and Zoll Defibrillator (Fig. 22). Similarly USC will also be using an IV pump to conduct research to assess through the suit – IV administration.



**Figure 22. Proposed layout of FDA display.** *The defibrillator (left) was launched with Shuttle Transport System (STS)-122) October 7, 2002. The LifePAK 1000 was used in Johnson Space Center as training hardware. The PCBA unit was launched within the AMP July 1, 1997 aboard Shuttle Columbia (STS-94) and the IV pump flew aboard Space Shuttle Endeavour during Shuttle Transport System (STS) -111.*

### III. Conclusion

The process of redesigning operations and certifying for flight involves careful planning, in depth research, and collaboration amongst many organizations. Through this internship it was discovered how the Medical Kit Redesign drove other projects and propagated through design work, research efforts, and community education. The Author learned how the work of one individual often depends on another.

The student also gained a deeper appreciation for the design process. From the Senior Design Training received at Milwaukee School of Engineering, great emphasis was placed on market analysis, regulations, standards, cost analysis, and failure modes and effects. The Medical Kit Redesign project put those assessments into perspective because each was involved throughout the phases of certification. A lot can be learned in industry and the community about the Flight Hardware Design Process Model (Figure 7). Issues and potential contingencies are addressed by the community through RIDs and the design is modified to implement a countermeasures contributing to the safety of crewmembers. If industry and educational institutions would implement this stringent analysis of hardware less accidents and higher quality machines would reach market.

Lastly the student learned why employers seek well rounded employees. Well rounded employees are able to integrate a variety of tasks while remaining on schedule, being organized, and working efficiently. This is often demanded in the workplace because low priority tasks could become high priority overnight, it is important to remain flexible and maintain balance while completing assignments. All students prior to graduating should participate in internships/co-op opportunities. Educational institutions teach students how to think and how to solve problems with available resources (e.g. professors, textbooks, etc.). If students learn how that translates to the workforce then the remaining semesters of college can be used to refine those skills resulting in an easy transition upon graduation.

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